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Innovative Dredged Sediment Decontamination and Treatment Technologies

PURPOSE: This technical note describes the dredged sediment decontamination and treatment technologies presented at a U.S. Section of the International Navigation Association (PIANC) Specialty Workshop held in Oakland, CA, 2 May 2000. It also presents a discussion of the barriers to technology implementation and the pertinent findings and conclusions of the workshop.

BACKGROUND: The Innovative Technologies (IT) Focus Area of the Dredging Operations and Environmental Research (DOER) program emphasizes identifying and evaluating innovations in dredging operations, processes, equipment, and techniques developed by the dredging and dredging-related industries worldwide. As part of this effort, DOER IT uses workshops and professional meetings to bring together key individuals from academia, industry, and government to exchange information and innovations on state-of-the-art technologies for dredging and dredged material management. On 2 May 2000, the U.S. Army Engineer Research and Development Center and New York District and the U.S. Section of PIANC sponsored the first Specialty Workshop, "Innovative Dredged Sediment Decontamination and Treatment Technologies," in Oakland, CA, as part of the U.S. Section's annual meeting. Cooperating organizations were the Western Dredging Association, American Association of Port Authorities, U.S. Environmental Protection Agency (USEPA) (Region 2), and USEPA Hazardous Substance Research Center (South/Southwest Region).

INTRODUCTION: Waterborne cargo alone contributes more than $742 billion to the U.S. gross domestic product and creates employment for more than 13 million citizens (U.S. Department of Transportation 1999). Vessels of the future, though more cost-efficient transporters, will need deeper waterways. Consequently, dredging requirements in the future will increase with this increased demand for navigable depth, resulting in an increase in generation of dredged material, including contaminated dredged material (CDM).

Estimates of the size of the contaminated sediment problem vary widely with a high degree of uncertainty associated with all the estimates. The Marine Board in 1997 stated that approximately 10.7 to 21.4 million cubic meters (14 to 28 million cubic yards (MCY)) of contaminated sediments out of an average of 216 million cubic meters (283 MCY) that are dredged each year have been identified as requiring special management (Committee on Contaminated Sediments 1997). Regardless of the size of the contaminated sediment problem, the Corps of Engineers and ports must manage increasing amounts of CDM from maintenance dredging each year.

Increasing controversy over adequate management of CDM also adversely impacts the Nation's waterborne transportation infrastructure and commerce by stopping or delaying dredging projects. Notable examples include dredging projects in the New York-New Jersey area and the Great Lakes. In addition, the Nation is facing a monumental task in managing contaminated sediment outside navigation channels without the benefit of cost-effective sediment remediation technologies.

Innovative management solutions for these sediments must include affordable decontamination, treatment, and beneficial uses of the residual end products.

Treatment is defined as a way of processing CDM with the aim of reducing the amount of contaminated material or reducing the contamination to meet regulatory standards and criteria. Treatment techniques are available for different types of contaminants in CDM. Some of these techniques are still in a demonstration stage, while others are approaching large-pilot scale or full-scale operations. Because the CDMs may contain various mixtures of heavy metals, petroleum hydrocarbons, and organochlorine compounds, they present a formidable challenge to treatment or decontamination technologies. Therefore, significant innovation will be required to develop a viable treatment or decontamination scheme to solve the problem of CDM in navigation projects.

To address the problem of contaminated sediments in navigation projects worldwide, in 1998, PIANC Permanent Technical Committee I, Working Group No. 17, published a two-volume report CD-ROM entitled, "Handling and Treatment of Contaminated Dredged Material (CDM) from Ports and Inland Waterways" (PIANC 1998). This was the first international document on the comprehensive management and treatment of CDM from navigation projects.

Chapter 5, Volume 1, of the report covers dredging project requirements. The report summarized the status of treatment of CDM as follows:

- A wide variety of treatment techniques are available for CDM. The currently available technologies can destroy, remove, or immobilize all types of contaminants and are applicable to almost all types of CDM. The costs of treatment are still high, but are decreasing.
- Full-scale separation and dewatering techniques are already being used internationally. Landfarming, bioslurry treatment, flotation, and gravitational separation are very promising, lower cost techniques and have been used at full scale at a few sites. Thermal treatment technologies have been used at a number of very highly contaminated sites in North America with success, but at high costs.
- Each dredging project involving CDM is a unique situation that demands a "custom- fitted" solution. For each site, the optimal combination of treatment techniques must be determined by weighing technical, economic, and environmental aspects. As placement costs continue to rise, treatment of CDM will become more attractive.

RELATED RESEARCH AND DEVELOPMENT PROGRAMS: Sediment treatment has received much attention in recent years. Several research and demonstration programs are aimed primarily at the need to develop technologies for handling and treatment of contaminated sediments from freshwater and marine ecosystems. Programs have been completed in the Netherlands, Belgium, Germany, Canada, Japan, and the United States (Averett et al. 1990; PIANC 1998; Tetra Tech and Averett 1994). Two pertinent programs conducted in the United States are briefly described in the following sections.

Assessment and Remediation of Contaminated Sediments. The 1987 amendments to the Clean Water Act, particularly Section 118(c)(3), authorized the USEPA Great Lakes National Program Office (GLNPO) to coordinate and conduct a 5-year study and demonstration project

relating to the appropriate treatment of toxic pollutants in bottom sediments. Five areas were specified in the act as requiring priority consideration in conducting demonstration projects: Saginaw Bay, Michigan; Sheboygan Harbor, Wisconsin; Grand Calumet River, Indiana; Ashtabula River, Ohio; and Buffalo River, New York.

To fulfill the requirements of the act, GLNPO initiated the Assessment and Remediation of Contaminated Sediments (ARCS) program. The ARCS program completed a number of studies describing alternative physical, chemical, and biological treatment processes and approaches for design and implementation of treatment (Averett et al. 1990; USEPA 1994; PIANC 1996). The ARCS program concluded that many technologies are available for treating contaminated sediments, and that treatment is generally the most costly component with the least amount of full-scale experience and will require additional development for full-scale application. The level of experience in sediment remediation, particularly with treatment processes, is very limited, and there is a high degree of uncertainty with the estimates of costs and contaminant losses from most of these technologies. Reliable cost estimates are developed only through the experience that comes from the execution and observation of multiple full-scale remediation projects.

Water Resources Development Act. The Water Resources Development Acts (WRDA) of 1990, 1992, 1996, and 1999 authorized funding for the purpose of demonstrating on a commercial scale (up to 382,277 cu m (500,000 cu yd)) the capability to decontaminate contaminated dredged material from the harbors of New York/New Jersey. The WRDA Decontamination Program has resulted in the development and evaluation of both thermal and nonthermal technologies from the laboratory and bench scale to the pilot and field scale. The goal of the WRDA Decontamination Program is the construction and implementation of one or more sediment decontamination facilities that result in a treatment train capable of producing a viable end product for beneficial use applications such as construction or fill materials and agricultural grade topsoil (Jones et al. 1998). Many of the technologies evaluated for the New York/New Jersey harbor sediments were reviewed during this PIANC Specialty Workshop.

PIANC SPECIALTY WORKSHOP: Approximately 100 people attended the workshop, representing the navigation industry, private consulting, environmental regulatory agencies, and academia. The purpose of the workshop was to conduct a critical review of selected technologies available for treating contaminated dredged sediments from navigation projects. In addition, the beneficial use potential for each technology was assessed. Six invited speakers from private industry gave presentations. Two luncheon speakers provided information on technologies used in Europe. Technologies presented by the speakers included soil washing, flowable fill, stabilization/solidification, electrochemical treatment, and production of blended cement, bricks, glass aggregate and lightweight aggregate. A panel consisting of representatives from the navigation industry, private consulting firms, and academia reviewed the technology applications (Figure 1).

The speakers were requested to focus their presentations on the ability of their technologies to handle the volumes of sediment and production rates typically associated with large-scale navigation dredging projects. They were requested to address the following topics:

Figure 1. Review panel

(1) Technology Description and Technology Availability

- Description of the technology and its unique characteristics
- Marketable products produced
- Current availability and scale of demonstration
- Capability of Technology Development Firms (TDFs) to fully implement technology

(2) Applicability to Large-Scale Navigation Projects

- Quantity of dredged sediment (or other media) on which technology has been demonstrated
- Demonstrated ability to process dredged sediment (or other media) in excess of 35,000 cubic yards per month

(3) Logistical and Regulatory Requirements

- Degree of incorporation of the technology in an overall sediment management program
- Amount of site preparation and required utilities for operation of technology plant
- Particular facility siting requirements *including land area*
- Environmental and/or regulatory barriers to technology implementation

(4) Net Cost

- Potential profit from sale of product resulting from applying technology to dredged sediment
- Estimated costs for ranges of dredged sediment production rates and project size/duration including production costs, delivery costs, and tipping fees

- Particular physical and/or chemical characteristics of dredged sediments that significantly impact costs

The speakers were also requested to address the following factors where applicable, particularly for those technologies that have not been demonstrated on dredged sediments on a large scale:

- Current state of technology development and time required for commercialization
- Factors affecting technology performance when applied to dredged sediments
- Estimates of performance for application of the technology to dredged sediment remediation
- Factors affecting economics of the technology
- Estimates of the capital and operating costs for the technology for ranges of project sizes
- Examples of application of the technology to dredging projects or remediation of contaminated sediments
- Unknowns or potential problems associated with applications of the technology to dredged sediments
- Health, safety, and environmental risks or related areas of concern associated with application of the technology to dredged sediments

At the conclusion of the presentations, the technical review panel and the audience were invited to ask questions and provide comments. The review panel then provided a brief comparative analysis of each technology as a means of clarifying the information presented and stimulating further discussion between the presenters and the audience. After completion of the comparative analysis, the technology presenters and the review panel led an open discussion on barriers to implementation of the technologies on dredged sediments. Barriers from the perspective of both the technology development firms and potential users were identified. Possible solutions or ways to reduce or overcome the barriers were also discussed.

DESCRIPTION OF TECHNOLOGIES REVIEWED: The technologies reviewed are categorized under two groups. The first category of technologies consists of those that achieve significant contaminant destruction using thermal processes including the following:

- Blended cement
- Building bricks
- Glass aggregate
- Lightweight aggregate

The second category of technologies comprises those that use primarily contaminant containment or partial contaminant removal processes including the following:

- Flowable fill

- Electrochemical remediation
- Soil washing
- Solidification/stabilization

CONTAMINANT DESTRUCTION USING THERMAL PROCESSES

Blended Cement. The Cement-Lock Technology is marketed by ENDESCO Services, Inc., Des Plaines, IL. Cement-Lock is an advanced thermochemical manufacturing process for decontaminating wastes including dredged sediments, soils, and sludges, and producing a marketable resource. Using this technology, dredged sediment can be transformed into construction-grade cement that meets ASTM standards (i.e., a dry cementlike product, not a concretelike matrix). During the process, organic contaminants are destroyed with destruction efficiencies greater than 99 percent. Heavy metals are immobilized in the cement matrix thus limiting their mobility and allowing for meeting Toxicity Characteristic Leaching Procedure (TCLP) regulatory criteria.

In operation, the water content of the dredged sediment (or other waste) is reduced using waste heat from the thermal process. The sediment is then transferred into a proprietary kiln identified as an ECOMELT™ Generator where fuel, air, and modifiers are introduced. A clinker-type material, produced in the ECOMELT™ Quench Unit, is transferred to a pulverizer/mixer where additional additives are introduced and mixed resulting in the Cement-Lock product. Modifiers and additives used in the process are formulated based on the chemical and physical characteristics of the sediment (or other waste) feed stream. Off-gas from the kiln is treated in a secondary combustion chamber; heat from the gas is recovered for use in drying the feed stream; and the gas stream is passed through a final cleanup process prior to discharge.

Building Bricks. Bricks for building are manufactured from contaminated dredged sediment by Hanseaten-Stein Ziegelei GmbH in Hamburg, Germany. Using this technology, dewatered contaminated sediments from the Port of Hamburg are used in the production of regular bricks suitable for use in the building industry. During the drying and ceramization process, organic contaminants are oxidized and metal contaminants are converted to stable immobile compounds or are volatilized.

In operation, the fine-grained portion of dewatered dredge sediments is used as the raw material for the bricks. The sediments dredged from the Port of Hamburg are dewatered and segregated in a system operated by the port prior to being transported to the Hanseaten-Stein facility. Analytical data indicate that a large percentage of the contaminants are associated with the fine-grained fraction (less than 63 μm) of the sediment. At the manufacturing facility, the sediment is mixed with natural clay and ground brick in a pan mill. The mixture is dried from 30 percent moisture to below 2 percent moisture content using a steam dryer. The water removed (in the form of vapor) is condensed and treated using an activated carbon system. The mixture from the steam dryer is dry-pressed to form the bricks, which are then placed in a kiln. The bricks are dried at a temperature of 600 °C (1,112 °F). The temperature is then increased to 1,066 °C (1,950 °F) for the ceramization process. The bricks are cooled and prepared for shipment. Flue gas from the process is treated with calcium hydroxide and activated carbon, and passed through a fabric filter prior to discharge.

Glass Aggregate. The Plasma Vitrification Technology is marketed by Global Plasma Systems Corporation, Washington, DC, in partnership with Westinghouse Plasma Corporation. Plasma vitrification is a high-temperature thermal process for converting waste to energy and decontaminating wastes including dredged sediments, wastewater sludge, and biosolids. Using this technology, dredged sediments can be transformed into molten glass and cooled to form glass aggregate. The aggregate can be used as a raw material in the manufacture of architectural tile, glass fiber, sandblasting grit, roadbed aggregate, and roofing granules. During the process, organic contaminants are destroyed by combustion with destruction efficiencies greater than 99 percent achieved. Heavy metals, along with mineral phases, are fused into glass, thus limiting their mobility and meeting TCLP regulatory criteria.

In operation, the dredged sediment is screened and partially dewatered using conventional techniques. Desalination of the sediment is conducted using an unidentified process. The sediment is then injected in front of a plasma torch with temperatures in excess of 5,000 °C. Fluxes are added to modify the properties of the final product. The molten material is collected in an associated chamber and passed through a quench chamber from which the vitrified product is collected. The glass aggregate is shipped offsite to conventional manufacturing operations where the final products are produced.

Lightweight Aggregate. The HarborRock Technology is marketed by HarborRock Holdings, Glen Mills, PA. HarborRock is a thermal process for decontaminating dredged sediments and producing a marketable product. Using this process, dredged sediment can be transformed into lightweight aggregate for use in building material applications. During the process, organic contaminants are thermally destroyed with destruction efficiencies greater than 99 percent. Heavy metals are immobilized in the aggregate, thus limiting their mobility and meeting TCLP regulatory criteria.

In operation, the dredged sediment is screened to remove large stones and debris, and then dewatered using mechanical and thermal processes. The dewatered sediment is then processed in a combined grinding and thermal drying process to achieve a uniform consistency. After cooling, the material is mixed with water and extruded into pellets approximately 13 mm (0.5 in.) in diameter by 25 mm (1 in.) long. The pellets are then fed into a kiln for firing at a temperature in excess of 982 °C (1,800 °F) where they expand to about 1.3 times their original size. The aggregate is then cooled and stockpiled. Off-gas from the kiln is cooled, with the heat recovered, recycled, and used elsewhere in the process, and passed through a final cleanup process prior to discharge. Residue from screening is landfilled.

CONTAMINANT CONTAINMENT/PARTIAL REMOVAL PROCESSES

Flowable Fill. The Flowable Fill technology presented is marketed by Pohlman Materials Recovery, Cary, IL. This technology is a nonthermal, mixing process using chemical additives to transform dredged sediments into a flowable construction fill product. During the process, contaminants are not destroyed, but their mobility is reduced due to chemical stabilization and incorporation in the physical matrix of the product. Reduction in mobility of two to three orders of magnitude is not unusual depending on the contaminant species.

In operation, the dredged sediment is screened to remove large debris and then transferred to a blending mixer. Some dewatering of the sediment may be required prior to processing. Proprietary silicate binders and fine aggregate waste material are added to the mixer and the water content is adjusted until the mixture is thoroughly blended. Once blended, the product is transferred directly to mixer vehicles for immediate transport to the place of use. The product requires immediate use and cannot be stored for any extended period of time. No off-gas requiring treatment is generated during the process.

Electrochemical Remediation. ElectroChemical Remediation Technologies (ECRT) are marketed by Weiss Associates, Emeryville, CA, under license to the European technology developer. There are two principal ECRT technologies: (1) ElectroChemical GeoOxidation (ECGO), which mineralizes organics to their inorganic components (e.g., carbon dioxide and water), and (2) Induced Complexation (IC), which enhances the mobilization of metals to be plated on electrodes. These technologies can be used as ex situ or as in situ processes. The technologies are based on imposing a direct electrical current through the contaminated material with a superimposed alternating energy current using buried electrodes. The superimposed electrical field creates an induced polarization effect in the sediment that, in turn, induces redox reactions that decompose organic contaminants through ECGO and provide enhanced mobilization of metals through IC. Removal efficiency is contaminant specific, and the treatment process treats clays and silts much faster than coarse-grained sand and gravel. The process does not produce a final marketable product, but rather affects a reduction in contaminant concentrations thus allowing (1) the sediment to be left in place, (2) the sediment to be disposed of as nonhazardous, or (3) the sediment to be reused as a soil-like product after further processing.

For application of the technology, the sediment is treated in situ or in a confined area. Electrodes are installed either through borings in the material or as sheet piles on approximately 10-m centers. Local electrical power is passed through proprietary d-c/a-c converters, and then the current is applied to the sediment through electrodes implanted in the sediment. Optimum remediation is generally achieved in less than 6 months.

Sediment Washing - BioGenesis. Advanced Sediment Washing Technology is marketed jointly by WESTON and BioGenesis, West Chester, PA. This technology is a multistaged sediment washing and organic oxidation process for decontaminating dredged sediments and producing a marketable fine-grained soil-like product for reuse after the addition of bulking materials. During the process, organic material is stripped from the solid particles and chemically oxidized. Removal efficiency is contaminant specific.

In operation, the dredged sediment is screened, and then high-pressure water and chemical cleaners are used to strip the outer layers of organic material from the sediment particles. Floatable organic material is removed using air sparging. Organic and inorganic materials are stripped from the sediment particles using high-pressure water and chemicals in a collision chamber. Organic material is oxidized by means of chemical oxidizer addition and processing in a cavitation unit. The treated sediment slurry is dewatered using a centrifuge and hydrocyclone. Bulking materials are added and mixed to produce a manufactured soil. Wastewater from the process is recycled into the process and/or treated and discharged.

Solidification/Stabilization. The solidification/stabilization technology presented was developed and used by the OENJ Cherokee Corporation, Bayonne, NJ, for cover at an old city landfill in Elizabeth, NJ, using dredged sediment. This technology is a nonthermal, mixing process using chemical additives to transform dredged sediments into a structural-cover product. During the process, contaminants are not destroyed, but their mobility is reduced due to chemical stabilization and incorporation in the physical matrix of the product. Reduction in mobility is dependent on the contaminant and the type and amount of chemical additives used.

In operation, the dredged sediment is screened to remove large debris and then transferred to a pug mill. Solidification additives (portland cement was used for this particular project) are added and mixed into the sediment. The resulting mixture is transported to the work site where it is allowed to dry and gain strength as a result of hydration of the additives. The material is then spread and compacted to provide a smooth, hard surface.

SUMMARY: The focus of the Specialty Conference was on technologies that are generally applicable to contaminated sediments and that have the potential to process large amounts of sediments, that is, sediment quantities in excess of 764,555 cu m (1,000,000 cu yd). Essentially all dredged material decontamination and treatment technologies that are capable of processing in excess of 764,555 cu m (1,000,000 cu yd) of dredged material fall into one of two basic categories, destruction technologies and technologies that separate/extract or stabilize contaminants.

Most destruction technologies are essentially thermal, since nonthermal-based destruction technologies are generally not available for some contaminants. Sediment decontamination technologies that are capable of processing large volumes of dredged material are designed to avoid disposal costs of product materials. They are designed to produce a salable product material.

EVALUATIONS: The important information and features of the eight technologies presented during the workshop are summarized in Table 1. Some of the information is incomplete because it was not presented by the TDFs. In comparing technologies, it should be noted that the technologies vary in their maturity and scale of demonstration. Capital and operation and maintenance costs are highly dependent on specific site conditions, dredged sediment characteristics, and the product produced.

Among the separation and stabilization technologies that have been proposed for contaminated sediments are sediment washing and processes that seek to produce fill material in which the contaminants are effectively contained. Soil washing technologies serve to reduce contaminant levels by partial removal of fines and organic material containing contaminants. The net result is contaminant reductions, by factors of 2-10, of the more soluble constitutents in the sediments. Reductions in contaminant levels of less soluble components, such as polychlorinated biphenyls (PCBs) or high-molecular-weight polycylic aromatic hydrocarbons (PAHs), are likely to be less than a factor of two. In many situations, this may be insufficient to allow significantly expanded uses of the treated material over the untreated dredged material. The goal of most soil washing technologies is production of a soil for beneficial use.

Stabilization technologies introduce additives to the dredged material to produce flowable or solid fill material. The contaminant levels are normally unchanged except for dilution due to the additives

Table 1
Comparative Summary of Decontamination/Treatment Technologies

Evaluation Factors	Technologies							
	Blended (Construction-Grade) Cement	**Building Bricks**	**Glass Aggregate**	**Lightweight Aggregate**	**Flowable Fill**	**Electrochemical Remediation**	**Sediment Washing**	**Solidification/ Stabilization**
Demonstrated on sediments	Sites in New York, New Jersey, and Michigan	Port of Hamburg, Germany	New York Harbor	Various Sites	Sites in New York	Port of Hamburg, Germany, and Union Canal, Scotland	Upper Newark Bay	New Jersey New York
Scale of demonstration	Pilot scale (1 ton/day)	Full scale (35,000 metric tons/year)	Pilot scale (13.4 cu yd)	Bench scale	Full scale (200,000 tons/year)	Bench scale (100 liters); field scale (220 cu m)	Bench and pilot scale (10 cu yd/hr)	Full scale (750,000 cu yd)
Effect on contaminants	Organics thermally oxidized; metals immobilized in cement matrix	Organics thermally oxidized; metals immobilized or valatilized	Organics thermally oxidized; metals immobilized in glass	Organics thermally oxidized; metals immobilized in aggregate	Reduced mobility due to stabilization and incorporation in physical matrix	Organics decomposed by redox reations; metals mobilized to electrodes where they are deposited	Organics are oxidized; metals are removed	Incorporated in physical matrix of product
Commercial availability	Process not applied to sediments on commercial basis; equipment available	Being conducted on commercial baasis; equipment available	Process not applied to saediments on commercial basis; equipment unique to process	Process not applied to sediments on commercial basis; equipment available	Process commercially available	Process not applied to sediments on commercial basis; equipment configured specifically for each site	Process not applied to sediments on commercial basis; some of the equipment is custom designed and fabricated	Process commercially available

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Table 1 (Continued)

	Technologies							
Evaluation Factors	**Blended (Construction-Grade) Cement**	**Building Bricks**	**Glass Aggregate**	**Lightweight Aggregate**	**Flowable Fill**	**Electrochemical Remediation**	**Sediment Washing**	**Solidification/ Stabilization**
Beneficial uses	Cement for general construction, soil stabilization, and solidification	Commercial/ residential construction	Architectural tile; glass fiber; blasting grit; aggregate; glass cullet	Geotechnical fill; concrete/ masonry aggregate; horticulture; road paving	Replacement for compacted fill	Manufactured soil by addition of bulking materials if sediment removed from site	Manufactured soil by addition of bulking materials	Compacted fill; capping
Siting requirements	Land area for melter and material storage; water, fuel, and power utilities	Land area for kiln and material storage; water, fuel, and power utilities	Land area for plasma arc facility; dewatering and desalination facilites; water, fuel, and power utilities	15 acres plus material storage; water, fuel, and power utilities	Land area for batch plant and material storage; water and power utilities	Process is conducted either ex situ or in situ; power utilities	15 - 25 acres for 250,000 cu yd/ year facility; water and power utilities	Land area for mixing equipment, additive storage; power utilities
Waste streams generated	Debris from screening; off-gas	Debris from screening; wastewater; off-gas	Debris from screening; wastewater	Debris from screening; wastewater; off-gas	Debris from screening; wastewater	Limited residues (sediment remains in place if conducted in situ); electrodes with deposited metals may require disposal or recycling	Debris from screening; limited air emissions; limited waste-water; nonhazardous sludge from water treatment system	Debris from screening
Permits required	Air; solid waste	Air; wastewater; solid waste	Air; wastewater; solid waste	Air; wastewater; solid waste	Wastewater; solid waste	None Identified	Air and wastewater discharge; recycling	Recycling

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Table 1 (Concluded)

Evaluation Factors	Technologies							
	Blended (Construction-Grade) Cement	**Building Bricks**	**Glass Aggregate**	**Lightweight Aggregate**	**Flowable Fill**	**Electrochemical Remediation**	**Sediment Washing**	**Solidification/ Stabilization**
Capital costs	$100 million for 500,000 cu yd/ year	$25 - $80 million (brick plant only; 300,000 - 900,000 metric tons/year of sediment)	$80 - $90 million (500,000 cu yd/year of sediment)	Not provided	Not provided	Not provided	$8 - $15 million (500,000 cu yd/year of sediment)	Not provided
Processing costs	$45 - $50/cu yd	$25 - $75/ metric ton	Not provided	Not provided	$12 - $20/cu yd	$130/cu yd for 3,000 cu yd to less than $33/cu yd for volumes greater than 100,000 cu yd	$160/cu yd for 30,000 cu yd/year to $20/cu yd for 500,000 cu yd/year	$56/cu yd (includes sediment dredging, transportating, and treating)
Tipping fee required	$0 - $35/cu yd	$20 - $60/ metric ton	$25 - $29/cu yd	$15 - $30/cu yd	$5 - $20/cu yd	Included above	Included above	Included above

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or the mixing with other fill components. The resulting stabilization, however, is expected to significantly reduce the potential for leaching of the contaminants. A significant barrier to use of the resulting material, however, is the lack of regulatory standards for use of the product. Fill product criteria based upon total contaminant levels are not likely to significantly expand the potential uses of this material while fill product criteria based upon regulatory leaching tests may not receive sufficient community acceptance.

Thermally based treatment/destruction technologies have the advantage of significant destruction of at least the organic contaminants in the dredged material. Conventional incineration faces significant community acceptance issues despite the potential for achieving essentially complete destruction of the bulk of the contamination. The production of blended cement, lightweight aggregate, or glass from the dredged material is likely to receive greater community acceptance. The blended cement process includes dredged material with other components used to produce cement. The use of cement kilns raises air emissions permit and community acceptance issues similar to those for a conventional incinerator. The production of lightweight aggregate from dredged material employs rotary kiln technology for the destruction of contaminants and production of the aggregate, and similar air emission permitting and community acceptance issues arise. The production of glassy products from dredged material employing a plasma torch has been proposed. This process is related to the technology used for in situ vitrification and has similar energy requirements and capital costs. Despite the production of a relatively clean product, the plasma torch may be more applicable to small volumes of highly contaminated dredged material due to the energy requirements and relatively high cost per unit weight of treated material.

The treatment of CDM becomes more attractive if alternative management options, such as disposal in a less secure (and less expensive) landfill, are not available. Some benefit may be gained from partial decontamination; but if there is no potential for expanded use of the residual dredged material, it is unlikely that these processes can compete economically with direct disposal of the dredged material in a landfill. The products of each of these processes have the opportunity to offset part of the cost of treatment although introduction of these products to the marketplace in large volumes will likely significantly negatively impact their value in the marketplace. The costs of these decontamination processes are also likely to be high. An exception will be when a large-volume dredged sediment stream can be guaranteed to allow the economies of scale. It has been estimated, but not demonstrated, that all processes except the plasma torch technology can be applied for between $30 and $70 per cubic yard of dredged sediment if amounts greater than 100,000 cu yd per year for between 10 and 20 years can be guaranteed. The success of the various technologies and the products they produce currently depends upon community and regulatory acceptance of their respective operations and the proposed uses for the resulting products as well as demonstrated effectiveness at a competitive cost.

BARRIERS TO IMPLEMENTATION: A number of barriers to technology implementation have been identified:

- The integration of treatment technologies into overall dredged sediment management.
- Conventional short-term, competitive procurement processes that hinder capital investment and limit the ability of the TDF to buy supplies at the lowest possible price.

- Public prejudice against technologies/processes used to treat and manage sediments.
- Lack of consist or total absence of applicable state regulations.
- Intermittent, variable sediment characteristics associated with typical dredging projects.
- Required development of market and acceptance of products produced from dredged sediments.
- Resistance from labor groups to displacement of traditional products and associated jobs.
- Long-term liability and legal responsibilities associated with produced products.

POTENTIAL SOLUTIONS: A number of potential methods, activities, and procedural changes may aid in overcoming or minimizing such barriers:

- Long-term forecasting of dredging requirements and funding availability.
- Public funding of centralized dredged sediment storage and management facilities.
- Use of other waste streams to ensure a continuous feed stream to process.
- Processing of other waste streams to augment income.
- Partnering between TDFs to increase overall product markets.
- Decouple the end product from the treatment process.
- Mandate use of recycled dredged sediment products in public projects.
- Educate the public about the benefits associated with using recycled dredged sediment products.

Some of these changes will probably be required to foster and stimulate the implementation of these innovative decontamination and treatment technologies. Regardless of the type of decontamination or treatment technology chosen for a navigation project, one thing is for certain: the economic and environmental benefits will have to be clearly identified and articulated to project sponsors, the public, and other stakeholders before such a technology is selected for use.

ACKNOWLEDGMENTS

Technical Panel

- Co-Chairman, Tom Wakeman, Eastern Commissioner of the U.S. Section of PIANC
- Co-Chairman, Dr. Danny Reible, Chevron Professor of Chemical Engineering, Louisiana State University
- Member, Steve Garbaciak, Blasland, Bouck, and Lee, Inc.
- Member, Bob Hopman, Foster Wheeler Environmental Corp.
- Member, Frank Hamons, American Association of Ports Authorities
- Member, Mr. Craig Wardlaw, Headwater Environmental Services Corp., Ontario

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- John D. Pauling, Program Manager, Ports & Waterways Development, Roy F. Weston, Inc.
- Farhad Jafari, Manager, Engineering, OENJ Cherokee Corporation
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Workshop Organization

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